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REPROCESSING OF THE AVHRR RECORD TO PRODUCE AN AEROSOL CLIMATOLOGY OVER OCEAN

In response to CGMS Action 34.25

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Summary of the Working Paper

Contemporary industrialization and human activities have contributed to the release of large amounts of trace gases and aerosol particles. The changes in the amount of aerosol particles in the atmosphere have potential environmental (air quality) and climate consequences. Currently the only global long-term record of space-based estimation of aerosol amount is obtained from the NOAA/AVHRR instrument. Several algorithms varying in complexity and assumptions have been applied to the AVHRR radiances for retrieving aerosol optical thickness.

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1. EXECUTIVE SUMMARY

Contemporary industrialization and human activities have contributed to the release of large amounts of trace gases and aerosol particles. The changes in the amount of aerosol particles in the atmosphere have potential environmental (air quality) and climate consequences. Observation of trends in the composition of the atmosphere, including that of the amount of aerosol, is regarded as a measure of the consequences and one of the first signs of possible global change. In spite of their recognized importance for climate change aerosols are also one of the least understood factors that influence climate. This is mostly due to their highly variable chemical/physical characteristics and very complex interaction with the environment that ranges from the direct modification of radiative energy available for absorption to the indirect effects of changing cloud properties and precipitation.

Currently the only global long-term record of space-based estimation of aerosol amount is obtained from the NOAA/AVHRR instrument. Several algorithms varying in complexity and assumptions have been applied to the AVHRR radiances for retrieving aerosol optical thickness. The AVHRR Pathfinder Atmosphere (PATMOS) climate-scale dataset was generated at the NOAA/NESDIS/STAR by reprocessing the AVHRR radiance observations from the NOAA-7, -9, -11, and -14 polar-orbiting satellites. This dataset provides a nearly continuous record of atmospheric products (including aerosol optical thickness over ocean) spanning over 20 years from September 1981 to December 2001. Recently, a second round of reprocessing of the PATMOS data has been completed by using AVHRR observations retrospectively re-calibrated with MODIS radiances. The new data set, named PATMOS-x, has been extended to 2005 by including the AVHRR observations from the NOAA-15, -16, and -17 satellites. The daily orbital clear-sky radiances of the new PATMOS-x data (mapped into 0.5^{o}x0.5^{o} grids) are used to retrieve new aerosol optical thickness (AOT) values from the AVHRR channel-1 (0.63μm) and channel-2 (0.83μm) radiances over the oceans using a revised independent two-channel aerosol retrieval algorithm. The retrieved daily AOT values are further averaged to 1^{o}x1^{o} grids, and the latter are used to calculate the monthly, seasonal, and annual mean values of AOT. In a recent study conducted by scientist at NOAA/NESDIS/STAR, the PATMOS-x data set has been used to explore global and regional trends in aerosol optical thickness. The global trend from this study agrees with the findings in a NASA study, and shows a small decrease of the aerosol amount during the past twenty years (-0.018 per decade). On regional scales, the linear aerosol trends have different signs. Areas affected by emissions from developed western countries show a decrease, while those affected by emissions from the fast developing Asian countries show an increase of the aerosol amount.

1. 1 TRENDS IN THE AVHRR PATMOS AEROSOL DATA

The channel-1 AOT in the APTMOS-x data was used explore long-term regional and global changes in aerosol loading. Time-series of globally and monthly averaged AOT and its anomaly along with a linear regression of the anomaly is shown in Figure 1. The corresponding linear long-term trend (LLT) is ~-0.01/decade with a confidence level higher than 95%. Figure 2 further displays the LLT of annual mean AOT averaged over the globe and the two hemispheres. For comparison, the corresponding trends for aerosol optical thickness at 0.55μm from the NASA Global Aerosol Climatology Project (GACP) data are also displayed. The GACP aerosol products were also retrieved from AVHRR measurements but used a different calibration scheme, cloud screening technique, aerosol retrieval algorithm, and spatial resolution. Both aerosol datasets (PATMOS and GACP) show a decreasing tendency with a LLT of ~-0.018/-0.014, -0.033/-0.020, and -0.025/-0.01 per decade for the southern hemisphere (SH), northern hemisphere (NH), and globe, respectively. The decreasing tendency in the NH is more evident than in the SH in both datasets. Nearly all detected tendencies from the two datasets are above the 95% confident level except for the SH in the PATMOS data. This comparison indicates similar negative tendencies from two independent retrievals that use AVHRR measurements. This increases our confidence that the detected decreasing trend of global aerosol optical thickness in the past 20 years is likely a real tendency.

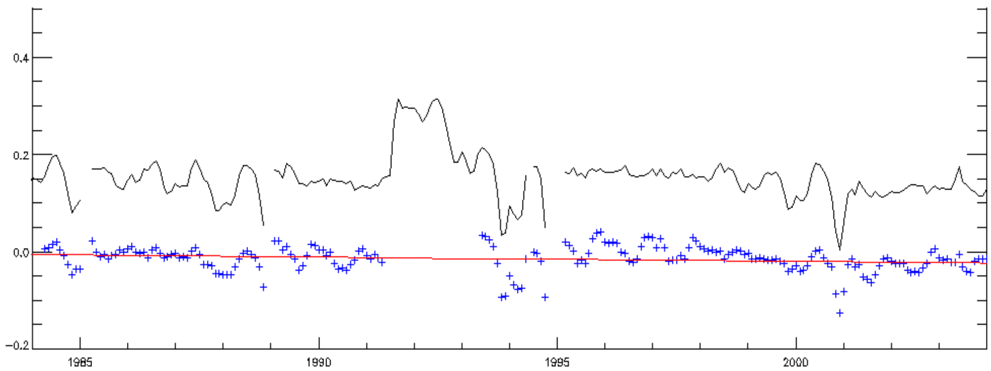

Figure 1. Time series of monthly averaged AOT (black curve) and its anomaly (blue plus sign) along with a linear regression of the anomaly (red line). The linear long-term trend (the slope of the regression line) is -0.01/decade.

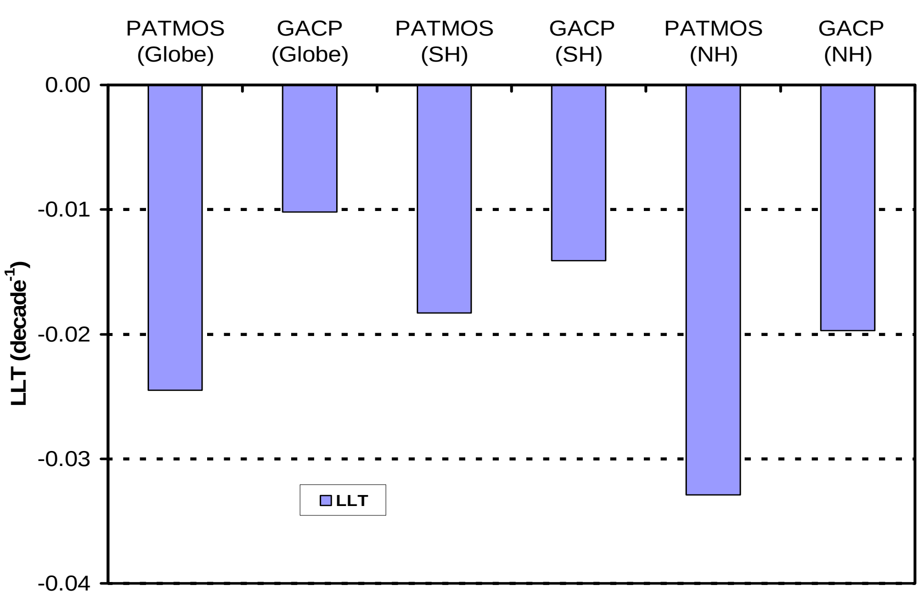

Figure 2. The linear long-term trends (LLT) of the annual mean aerosol optical thickness at 0.63μm from PATMOS and that at 0.55μm from the Global Aerosol Climatology Project (GACP) for the globe, southern hemisphere (SH), and northern hemisphere (NH).

In different regions of the globe the aerosol optical thickness shows very different seasonal variations, and its long-term trend is also expected to be different. We selected 18 regions (see Table 1) over the globe for a detailed regional analysis. These regions are mainly over the downwind areas of land emissions so that they are under the influence of aerosols originating from land sources (such as dust, industrial pollution, and biomass burning) and show evident seasonal variations. The LLT values of seasonally averaged AOT for the 18 regions, SH, NH, and the globe are summarized in Table 1.

Table 1. Global and regional LLT (AOT change per decade) of seasonally averaged AOT for winter (DJF), spring (MAM), summer (JJA), and fall (SON). Longitude (Lon) and latitude (Lat) coordinates of region boundaries are in units of degrees.

Regions [Lon-1, Lon-2; Lat-1, Lat-2]	LLT of AOT (1/decade)			
	DJF	MAM	JJA	SON
1. [12.0, 22.0; 32.0, 42.0]	-0.013	-0.033	-0.042	-0.002
2. [30.0, 40.0; 37.5, 47.5]	-0.064	-0.074	-0.099	-0.022
3. [45.0, 55.0; 37.0, 47.0]	-0.063	-0.086	-0.058	-0.004
4. [60.0, 70.0; 10.0, 20.0]	+0.026	+0.030	-0.011	+0.042
5. [82.0, 92,0; 10.0, 20.0]	+0.035	+0.028	+0.030	+0.035
6. [110.0, 120.0; 10.0, 20.0]	+0.005	+0.007	+0.001	+0.025
7. [125.0, 135.0; 25.0, 35.0]	+0.016	+0.005	+0.007	+0.024
8. [-75.0, -65.0; 30.0, 40.0]	-0.015	-0.021	-0.023	-0.022
9. [-30.0, -20.0; 10.0, 20.0]	-0.017	-0.032	-0.023	-0.016
10. [5.0, 15.0; -15.0, -5.0]	+0.002	+0.009	+0.013	+0.033
11. [32.5, 42.5; 15.0, 25.0]	+0.007	+0.011	+0.010	+0.027
12. [90.0, 100.0; -7.5, 2.5]	-0.010	+0.009	+0.011	+0.036
13. [-95.0, -85.0; 21.0, 31.0]	-0.006	-0.017	-0.030	-0.002
14. [-125.0, -115.0; 25.0, 35.0]	-0.005	-0.018	-0.010	-0.003
15. [-80.0, -70.0; 10.0, 20.0]	+0.008	+0.015	-0.015	+0.012
16. [-87.0, -77.0; -15.0, -5.0]	-0.000	-0.006	-0.016	+0.012
17. [-40.0, -30.0; -20.0, -10.0]	+0.002	-0.001	-0.009	+0.008
18. [-180.0, 180.0; -20.0, 20.0]	-0.001	-0.000	-0.002	+0.010
19. [-180.0, 180.0; 0.0, 90.0]	-0.006	-0.014	-0.015	+0.004
20. [-180.0, 180.0; -90.0, 0.0]	-0.006	-0.006	-0.008	+0.001
21. [-180.0, 180.0; -90.0, 90.0]	-0.006	-0.013	-0.017	-0.000

For the regions influenced by industrial pollutions from the developed countries (e.g., Regions 1, 2, 3, 8, 13, and 14), a negative trend is dominant. This negative tendency can be explained by decreasing industrial emissions in the developed countries during the past two decades due to environmental regulations. For the region influenced by Sahara desert particles (Region 9), also a negative trend is found, which is consistent with higher dust levels in the early 1980s (with a peak in 1983) and lower levels in the late 1990s. This tendency has also been observed from both surface in-situ measurements and from TOMS satellite observations. A positive trend is observed over the Regions 4, 5, 6, and 7. This is consistent with the fast growth in the economy and associated increase of industrial emissions in the developing countries, such as India, and China, in the last twenty years. For the regions influenced by biomass burning smoke in warm and dry season (e.g., Regions 10, 12, 16, and 17), the corresponding AOT long-term trend is also positive.

2. RECOMMENDATIONS

The aerosol dataset in PATMOS-x is at grid level resolution (rather than pixel level resolution) and is obtained from an independent two-channel algorithm that assumes constant gas amounts and surface conditions. Even if the calibration of the AVHRR channels are perfect, these limitations produce systematic errors in the retrieval of AOT, especially in channel 2 which is affected by water vapor absorption. This in turn affects the size parameter (Ångström exponent) that is dependent on the retrieved AOT in both channels 1 and 2. As a result, we are more confident in the sign rather than the magnitude of the long-term trend derived from the current study summarized above.

To overcome the limitations mentioned above and to reduce the uncertainties in the long-term aerosol trends one should re-derive the AOT record from AVHRR. This re-processing should include the following.

a) A dependent multi-channel algorithm should be used that retrieves AOT and size parameter simultaneously. For this to work, it is absolutely vital to have the best calibrated radiances available for all channels used in the aerosol retrieval.

b) Variable atmospheric and surface conditions should be considered in the retrieval process to minimize aliasing the variability in gas amount and surface condition into the aerosol time series.

c) Anthropogenic aerosols are produced mainly over land, and thus it is important to study the long-term trend of anthropogenic aerosols over land. Therefore, the AVHRR aerosol retrievals should be extended to land areas. It is well known that aerosol retrieval over land is much more difficult than that over ocean. However, a few research algorithms have already been developed for land over regional scales and extending these algorithms to global land may not be impossible. The quality and limitations of these algorithms should be established by comparing them to those obtained from more appropriate platforms (e.g., MODIS, CALIPSO, POLDER).